Anodal tDCS affects verbal episodic memory in initially low performers only

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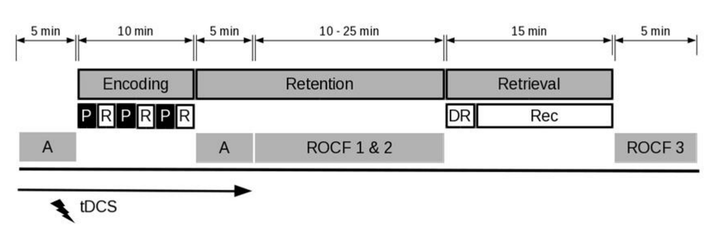
Background

Episodic memory (i.e. connecting information with a specific context [1]) is highly relevant for the daily routine but undergoes decline during healthy aging and neurodegenerative disease. As the left dorsolateral prefrontal cortex (DLPFC) is active during both encoding and retrieval of episodic memories [2] it has become a frequent target in brain stimulation paradigms that boost neuronal excitability (i.e. transcranial direct current stimulation, tDCS [3,4]). However, there appears to be great variability in the tDCS response. Previous studies found that baseline performance influenced stimulation gains insofar as low performers were more likely to profit than their high performing peers. While this relationship has been mainly studied in a dichotomous manner, here we investigate if the modulating effect of tDCS on episodic memory is moderated by baseline performance even in a homogenous population of healthy young participants.

Methods

In this double-blind, sham-controlled study with parallel design, 43 healthy young adults (aged 24.8 ± 2.9 years, 22 females) received either 20 min of 1 mA anodal tDCS or sham stimulation to their left DLPFC during the encoding phase of a verbal episodic memory task (Fig. 1). During the encoding phase 40 nouns, extracted from the HVLT-R [5] were visually presented in three successive blocks, each of which was followed by an immediate oral retrieval. During the retention interval of approx. 20 min, participants completed an alertness task and furthermore copied and immediately retrieved the Rey-Osterrieth figure [6]. During the retrieval phase, participants first performed a delayed recall of the memorized words , and then completed a recognition task. Group differences induced by the stimulation were assessed by a 4 x 2 repeated measures ANOVA with retrieval (i.e. immediate and delayed recalls) as within-subject factor and stimulation as between-subjects factor. To investigate if initial performance moderated the benefit of tDCS on the increase in recalled words between first and last retrieval, we used SPSS PROCESS macro [7] to perform a moderation analysis with stimulation (sham or real) as the focal predictor and midlist performance in the first retrieval as the moderator variable. Midlist performance in the first retrieval was chosen because it is uninfluenced by the serial position effect und thus better reflects baseline episodic memory ability [8].

Fig.1 Study procedure



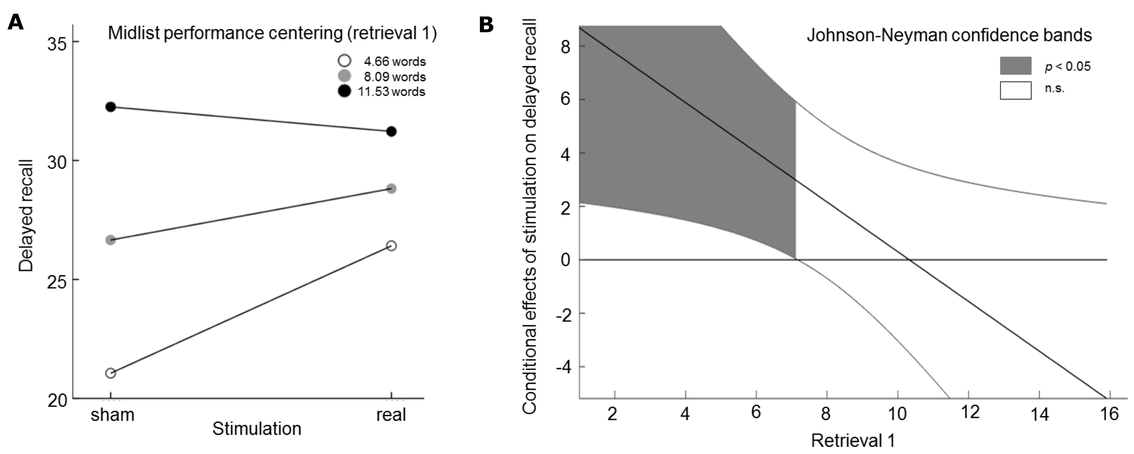
Encoding consisted of the presentation (P) and immediate retrieval (R) of 40 words in three successive blocks. After a retention interval, participants performed a delayed recall (DR) and a recognition task (Rec). The application of tDCS was restricted to the encoding phase.

Results

The overall fit of our moderation model reached significance ($F_{(3,39)}$ = 16.15, p < 0.0005, R^2 = 0.55). Therein, the simple effects of initial midlist performance ($t_{(39)}$ = 5.2, p < 0.0005), stimulation ($t_{(39)}$ = 2.74, p < 0.0009) and their interaction ($t_{(39)}$ = -2.31, p = 0.03) were significant. This indicates that initial low performers experienced the highest gain from stimulation on delayed recall (Fig. 3A, B).

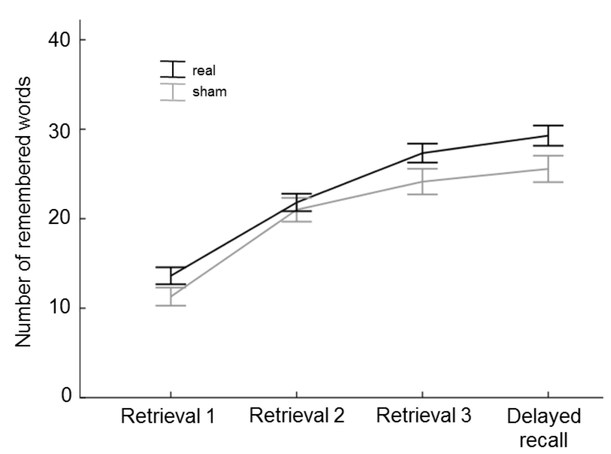
The 4 x 2 repeated measures ANOVA showed only a significant main effect of retrieval ($F_{(3,38)}$ = 242.73, p < 0.0005, η^2 = 0.86, Fig. 2) while no significant interaction between retrieval round and stimulation was found ($F_{(3,38)}$ = 2.18, p = 0.09) on the group level.

Fig.2 Moderation effects



A Moderation effect of midlist performance in retrieval 1 on relation between stimulation and performance in the delayed recall for three performance centerings (-SD, mean, +SD).
B Conditional effects of performance in the delayed recall. Johnson-Neyman confidence bands indicate the midlist performance range in retrieval 1, in which the latter has a significant predictive value.

Fig. 3 Words retrieved during immediate and delayed recall



Mean values and standard errors for performance in verbal episodic memory task during encoding and retrieval phase for both stimulation groups.

Conclusion

Notwithstanding that greater tDCS effect sizes have been attributed to both healthy older and neuropathologically afflicted populations [9], in the present study we showed that the favourable impact of tDCS on cognitive measures is not entirely restricted to specific populations. Individual baseline performance seems to be a more conclusive factor instead. Here, only initial low performers displayed tDCS-induced benefits in the delayed recall of a verbal episodic memory task. Similar inconsistencies regarding stimulation gains have been accumulating in the literature. However, previous studies often divided their participants in two distinct groups, according to the level of expertise in the examined task, whereas the chosen continuous evaluation allows a more realistic representation of encountered abilities. Exposing the variability of brain stimulation outcomes provides valuable insights regarding basic research but also steers application-oriented research towards the customization of tDCS protocols, especially with regard to the identification of probable beneficiaries prior to the treatment.

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